

Toward independent L2 readers: Effects of text adjuncts, subject knowledge, L1 reading, and L2 proficiency

Cindy Brantmeier
Washington University
United States

JoAnn Hammadou Sullivan
University of Rhode Island
United States

Michael Strube
Washington University
United States

Abstract

With 97 learners in an advanced Spanish course, the study examines the effects of textual enhancement adjuncts, prior subject knowledge, first language (L1) reading ability, and second language (L2) Spanish proficiency on L2 comprehension of scientific passages. Readings included two texts with two types of embedded questions: a pause or written answer. MANOVA was used to examine the main effects and interaction of textual enhancement adjuncts on three types of comprehension tasks. Findings revealed that embedded questions did not assist L2 readers to comprehend better. The effect of embedded questions on comprehension was not moderated by L1 reading ability, L2 overall proficiency nor by prior subject knowledge. Although prior subject knowledge and L1 reading comprehension were positively related to comprehension, the use of textual enhancements did not compensate for weaknesses. This study provided evidence that, with advanced L2 learners, embedded questions do not aid L2 reading comprehension.

Keywords: L2 reading, scientific texts, textual adjuncts, embedded questions

Teaching second language (L2) learners to become lifelong second language readers is a goal of many language programs (Bamford & Day, 1998), and obviously, creating independent L2 readers is fundamental. Recently, in a synthesis of research on L2 reading, Bernhardt (2011) contended that improvement in L2 reading at advanced stages, in the absence of an instructor or structured classroom, is of critical importance to the field. The present study is an attempt to investigate factors that may aid in the development of independent L2 readers who are processing upper-level, technical materials. More specifically, the present investigation considers

whether the interaction of textual enhancement adjuncts (embedded questions with pause or written answer) with subject knowledge, first language (L1) reading ability, and L2 proficiency, affects L2 reading comprehension (as measured via written recall, sentence completion, and multiple choice) among adults.

Review of Literature

Studies on Textual Enhancements for L2 Reading

Attempting proficient reading in one's L2 is often a long, arduous process, and educators continue to seek ways to help L2 readers experience success with this difficult task. L1 researchers have been building a research base on the importance of meaning-based processes for reaching achievement for some time (e.g., Van den Broek, 1994; Wise, Sevcil, Morris, Lovett, & Wolf, 2007). One promising avenue of study to assist L1 readers is in the area of text adjuncts, which include organizational cues (Lorch & Lorch, 1985), outlining (Glynn, Britton, & Muth, 1985), advance organizers (Ausubel, 1960), and various forms of questioning techniques (Callender & McDaniel, 2007; Hamaker, 1986; Peverly & Wood, 2001; Seifert, 1993; Walczyk & Hall, 1989). In L1 studies, adjunct questions, particularly those that are embedded within the text, increase comprehension (Hamaker, 1986). The facilitating effects were especially strong for readers with less knowledge of the text topic or less interest in it (Ozgungor & Guthrie, 2004). When the questions cued the readers to important information in the text, the readers seemed better able to construct a relevant mental representation of the text information that subsequently improved their performance on various comprehension assessments.

Researchers in L2 reading also seek aids that will assist readers to become successful, independent readers. Based on results from early L1 studies (Bean, Serles, & Cowen, 1990; Vosniadou & Ortony, 1983), Hammadou (1990, 2000) first investigated the potential facilitative effect of analogies on L2 reading comprehension with two versions (analogy/non-analogy) of two scientific passages. In the first study, neither an eye/camera analogy nor a pétanque/bowling analogy improved L2 readers' recall scores. In the second study, neither the eye/camera analogy nor a chain reaction/mice population explosion analogy improved readers' comprehension. In fact, all three analogy passages lowered readers' comprehension scores on a recall measure, and the eye/camera analogy significantly so in both studies. The negative effect of analogy held true regardless of other individual factors (participants' L1 or L2 proficiency levels, or subject knowledge). Likewise, in Brantmeier (2005) the addition of analogies to scientific texts did not compensate for the lack of subject knowledge. In her study there was no overall positive effect of analogic texts on both L1 and L2 comprehension as measured via recall, sentence completion, and multiple choice. A positive effect for the non-analogy version was reported for the recall task. More specifically, participants scored higher on the non-analogy version of both texts when assessed by the recall test; no such differences for either passage for sentence completion and multiple choice emerged. Overall, the evidence suggested that analogies are unlikely to serve as aids to comprehension for L2 readers. The question, then, is whether different types of textual enhancements will help the L2 reader.

To date, little research has investigated the effects of inserted adjunct questions with L2 readers.

Brantmeier, Callender, and McDaniel (2011) utilized two different reading passages from social psychology texts with advanced L2 learners of Spanish to examine the effects of embedded *what*-questions and elaborative *why*-questions on reading comprehension. Findings yielded significant effects of adjunct questions with one passage but not the other when comprehension was measured via written recall. The mean score for what-questions was slightly higher than the score for why-questions with the significant passage. It is important to also point out that the reading passage with positive effects of adjuncts was shorter than the counterpart, but the same number of adjuncts were inserted, and that participants were equally familiar with the content of both passages. The authors explained that the reliance on readers' prior knowledge may decrease with more adjunct questions within the text and that longer passages may need more inserted adjuncts. No significant effects of adjunct questions were found for either passage when comprehension was tested with multiple-choice items.

It is important to note that in Brantmeier et al. (2011) both what- and why-questions improved performance on recall, and that the mean score for what-questions was slightly higher than the score for why-questions. The advantage of what-questions with L2 readers contradicted prior L1 research on adjuncts where why-questions appear to improve comprehension better than what-questions with advanced L1 readers. The authors concluded that advanced L2 learners may benefit from basic what-questions that are inserted into domain specific texts. Given these results, the present study utilizes inserted what-questions with advanced learners.

Studies on Subject Knowledge

A plethora of L1 studies document the influence of prior knowledge on reading comprehension. For example, Anderson and Pearson (1984) gave an ambiguous reading passage to music and physical education majors. With a text that could have been describing a woodwind quartet or a card game and another that could have been a wrestler's hold or a prison escape, the special background of the readers guided their understanding of the piece. Stahl, Hare, Sinatra, and Gregory (1991) studied the effect of both prior topic knowledge and vocabulary knowledge on recall of a text on baseball. They found that vocabulary knowledge tended to affect the number of units recalled overall and that prior knowledge tended to influence which units were recalled.

In L2 research, for some time now background knowledge has also been demonstrated to play a significant role in comprehension (e.g., Bransford & Johnson, 1972; Brantmeier, 2002; Brantmeier, 2003; Bügel & Buunk, 1996; Carrell, 1984a; Carrell, 1984b; Hudson, 1982; Johnson, 1981; Mohammed & Swales, 1984; Pritchard, 1990; Schueller, 1999; Steffensen, Joag-Dev, & Anderson, 1979; Young & Oxford, 1997). Pioneering examples of this research include Johnson (1982), who gave English as a second language (ESL) readers a passage on Halloween and demonstrated that cultural familiarity had a greater impact on comprehension than did the pre-teaching of vocabulary. In a study primarily of the effect of analogy on reading comprehension, Hammadou (2000) found prior topic knowledge as tested by a 12-item multiple-choice test to be the most powerful factor affecting recall. In summary, findings from both L1 and L2 studies that include subject knowledge as a variable show that topic knowledge does impact reading comprehension. The challenge that remains is how to help advanced L2 learners successfully navigate texts for which they have limited prior knowledge. Perhaps enhancements or additions to a text may make comprehension easier.

L1 Reading Ability and L2 Reading

Recently, Bernhardt (2011) provided an extensive and detailed review of prior L2 reading research and theory that emphasizes the impact of L1 literacy skills and L2 grammatical knowledge. For example, Clarke (1980) investigated how L2 language competence interferes with L2 reading with learners of Spanish even for those who demonstrate good reading skills in their L1. Bernhardt (2011) carefully synthesized prior investigations to emphasize that readers who have difficulties with L1 reading will most likely struggle with L2 reading, and she urged future researchers to include L1 literacy as a variable for analysis in studies on L2 reading in order to provide more powerful and reliable findings. Following Bernhardt (2011), the present study asked participants to read two different L1 passages and complete recall comprehension tasks for those texts.

In Hammadou's (1990) pioneering analogy study, the overall tendency was for participants of high L1 verbal ability (as measured by the California Achievement Test verbal sections) to recall significantly more of what they read in their L2 than low L1 verbal ability readers. However, unlike some L1 studies (Alexander & Kulikowich, 1991; Vosniadou & Brewer, 1987) where interventions helped low-ability readers more than high-ability readers, there was a general lack of interaction between analogy treatment and L1 reading ability. In other words, the effect of the L2 analogy treatment did not change according to the readers' L1 verbal ability. Although the L2 analogies treatment results did not vary according to L1 reading ability, perhaps the addition of textual enhancements into the L2 text would aid participants with lower L1 reading abilities.

L2 Proficiency

Bernhardt's (2005) model of L2 reading emphasizes the important role that L2 language plays in L2 reading and specifies variables such as vocabulary and syntactic skills. More recently, Guo and Roehrig (2011) provided a comprehensive review of research that examined the role of L2 language knowledge in L2 reading, and once again they highlight factors such as vocabulary and syntactic skills. Guo and Roehrig also include metacognitive awareness as part of L2 language knowledge. They specifically mention that most of the research that examined the role of these variables in L2 reading had been conducted with L2 learners of English whose native languages were alphabetic. The present study controlled for L1 and L2 differences in writing systems as it utilized participants who were native speakers of English studying Spanish as a L2 in the USA. Therefore, L2 proficiency is an important factor considered in the present study on textual enhancements. In a current book on advanced second language reading, Bernhardt (2011) explained the difficulties involved in an examination of lexical acquisition during L2 reading because of the problem separating word learning from L2 reading comprehension. She also noted the inadequacies of prior studies that examined the role of syntactic knowledge in the L2 reading process. The present study did not attempt to isolate the two variables often referred to as language knowledge, but rather the investigation was an attempt to examine whether or not these important variables interact with textual adjuncts to influence comprehension. For the present study, the term L2 proficiency refers to four subconstructs: vocabulary, grammar, reading, and listening.

Type of Comprehension Assessment

Investigations have specifically examined L2 reader performance on a variety of comprehension assessment tasks (Carrell, 1991; Hammadou, 2002; Lee, 1990; Shohamy, 1984; Wolf, 1993). Brantmeier (2005) offers a detailed description of different types of tasks that are commonly utilized to measure L2 reading comprehension in an attempt to explain why the outcome of individual assessment tasks may not provide a full representation of reading comprehension. For some time now, Bernhardt (1991) has recommended that a variety of tasks should be used to examine reading comprehension so that researchers are better able to offer generalizations. Like Brantmeier (2005), the present experiment includes three different tasks for comprehension: written recall, sentence completion, and multiple-choice items.

Written recall requires no tester interference or retrieval cues. Immediately after reading the passage, readers were asked to write down what they could remember about the passage they just read. This unstructured task offers a more comprehensive depiction of the reader's understanding (Bernhardt, 1991; Bernhardt, 2011). Sentence completion is considered an open-response task that does not utilize retrieval cues. All possible and acceptable answers were predetermined, and the objectivity of scoring relied on the comprehensiveness of the answer key. The most widely used way to examine reading comprehension continues to be multiple-choice items that include retrieval cues. This method of assessment has been scrutinized for decades, mainly because all questions and answers are predetermined and answers are right or wrong, which is an incomplete or inaccurate reflection of true comprehension. For the present study, all items were passage dependent (Bernhardt, 1991; Wolf, 1993), and learners could not figure out answers from other questions on the test (Brantmeier, 2003). Following Wolf's (1993) rubric for the creation of multiple choice questions, each question had four possible answers that included one correct item and three plausible distractors. The reader had to understand the passage in order to answer each multiple choice question.

The recall for the present study was written in the reader's L1 (Lee, 1986; Shohamy, 1982, 1984; Wolf, 1993). Additionally, the remaining comprehension assessment tasks were also written in the reader's L1 of English.

The review of research that examines textual enhancements, subject knowledge, L1 reading abilities, L2 proficiency or knowledge, and test type leads to the following overall question: Do embedded questions inserted in the scientific passages make L2 reading easier?

The Present Study

The overall goal of the present study was to examine whether textual enhancements in the form of embedded questions improve L2 readers' comprehension of scientific texts. The following specific research questions guided this study:

1. With scientific texts, does subject knowledge affect L2 comprehension as measured via varied assessment tasks?
2. Do the effects on L2 comprehension of textual enhancements vary according to prior subject knowledge?

3. Do the effects on L2 comprehension of textual enhancement adjuncts vary according to L1 reading scores?
4. Do the effects on L2 comprehension of textual enhancement adjuncts vary according to L2 proficiency?

Participants

Participants were 97 university students enrolled in an advanced Spanish grammar and composition language course. This course marks the beginning of the Spanish major, and students must test into the course via an online exam that includes grammar, vocabulary, listening, and reading. At the university, there is no language requirement, and consequently students enroll in the course voluntarily. Most of the students who enroll in the advanced grammar course have declared a major or a minor in Spanish, where the major is usually a secondary major that complements a primary major in medicine, engineering, computer science, psychology, or some humanities-driven discipline. Students must achieve a certain score on an online placement exam in order to take the course, and therefore it may be said that there is not a wide range of L2 abilities among learners in the present study. The first language of all the participants was English, and all completed the full data collection procedures.

Data Collection Instruments and Procedures

Reading Passages

Two reading passages were taken from Hammadou (2000) and Brantmeier (2005) and were developed specifically for research purposes (two topics, three versions each, one without adjuncts, one with pause and consider adjunct, and one with pause and write adjunct). Appendix A includes selections in English from different versions of both passages. Scientific passages were used in order to reflect the growing trend of interdisciplinary study with scientific professions among L2 learners in the USA (MLA Ad Hoc Committee on Foreign Languages, 2009). Brantmeier (2005) examined the English version of each passage to identify syntactic complexity (Barry & Lazarte, 1995)¹. See Table 1 for a list of numbers of words and clauses for each version of both passages. The first passage explained the function of the human eye, and the second passage was about the chain reaction of nuclear fission. Like Hammadou (2000) and Brantmeier (2005), the present investigation utilized two different passages with different lengths and content to provide further evidence that the results would be generalizable to similar groups of participants.

Table 1. Number of Words and Embedded Clauses for Both Passage Versions in English

Passage topic		
Eye	Word count	159
	Embedded clauses	22
Chain reaction	Word count	241
	Embedded clauses	31

Assessment Tasks

Like Brantmeier (2005), the written recall asked the readers to write down in their L1 as much as they could remember about each passage. Following Wolf's (1993) guidelines, a response for each sentence completion question corresponded to an item in each multiple-choice question, and consequently respondents completed the sentence completion before the multiple choice questions. Given the length of the readings, five sentence completion and five multiple choice questions were included. Examples of comprehension test items in the three task formats appear in Brantmeier (2005).

Items for Subject Knowledge

A questionnaire of prior subject knowledge was administered after completion of assessment tasks for each passage. Each participant was asked to indicate the level of knowledge that he or she had, before reading the passage, with respect to the topic of the passage. The responses ranged from (1) I know a lot about the topic, to (5) The topic was totally unknown to me.

Online Spanish Language Exam

The online Spanish placement exam was designed for learners of Advanced Spanish and consisted of a total of 100 questions. The test consists of four different sections: vocabulary, grammar, reading, and listening. Students enrolled in Advanced Spanish were required to achieve a total score of 75 or higher, or they could not enroll in the course. The grammar section of the online test included 20 questions that varied in difficulty levels and included grammatical structures appropriate to beginning, intermediate, and advanced stages of instruction. The vocabulary section of the online diagnostic test consisted of 20 questions and reflected lexical items learned across beginning, intermediate, and advanced courses.

The reading section of the online diagnostic exam consisted of 30 total questions. The reading section included eight different passages of varying styles and lengths that were about history, daily lives, personal anecdotes, and encyclopedia-like topics. Each passage included corresponding multiple choice questions. All reading passages met the ACTFL proficiency guidelines for advanced readers. The listening section of the online exam included 30 questions and consisted of a variety of short dialogues and prose readings that emphasized the daily lives of students, historical events, or personal anecdotes. All questions were in multiple choice format and included four possible answers, and all incorrect answers were plausible. It is important to note that because the test involved four different sections, some students might have achieved a perfect score on one section and not done very well on another, and they might have still achieved the score necessary for enrollment in advanced Spanish. Students completed the online Spanish exam outside of class before the start of the semester during their own time in their own location.

L1 Reading Passages

Two different passages in English were read by each participant, and after reading each passage a written recall was completed in English. The recall for the L1 passages used the same instructions as the recall for the L2 passages. The first passage was entitled "The Wild Man of the Green Swamp" and consisted of approximately 360 words. It detailed the actions of a wild

man who was reportedly seen in a swamp in Florida. The second passage, entitled “Is English Degenerating?” included approximately 340 words and was about the English language degenerating into a sloppy and ungrammatical language.

Data Collection Procedures

Data collection took place during class time on two different days in the participants’ regular classrooms. Each participant received a packet containing the following: a consent form, two L2 reading passages, subject knowledge items, L2 recall comprehension tasks, sentence completion tests, multiple-choice comprehension tests, two L1 reading passages, and L1 recall tasks. Packets were randomly assigned one version of the L2 texts: a pause-and-consider-adjunct, a pause-and-write-adjunct, or without-adjuncts. All participants read four passages and completed all tasks.

The researchers or a research assistant, along with the classroom instructor, were present at all data collection sessions. The participants were told that they were invited to participate in a study on reading in Spanish, and that if they accepted the invitation to participate that they would read two different passages, and immediately following each passage they would answer a series of questions. The participants were instructed not to look back at any previous pages while completing the study. Once one page was completed, they turned to the next page and could not look back. These instructions follow standard L2 reading research practices (Bernhardt, 1991; Lee, 1986). The researcher or research assistant was present to ensure all participants followed the instructions. No students declined to participate in the study.

Scoring and Data Analysis

Like the studies by Hammadou (2000) and Brantmeier (2005), each written recall for both passages in both languages was scored according to procedures developed by Meyer (1985). Idea units were identified as content units and rhetorical idea units. The codifying process involved reading each written recall and then counting the number of correct content and rhetorical idea units a participant recalled for each scientific passage. Only correct idea units recalled from the passages were included in this present study². The total number of correct idea units was the index of recall for each passage. The researcher and research assistant prepared a list of correct and acceptable answers for sentence completion, and the sentence completion items were scored with this template as a basis. The total number of correct answers was counted for the dependent variable of sentence completion. The total number of correct answers was counted for the dependent variable of multiple choice. All scores were submitted to correlational analysis to determine interrater reliability. Raters agreed on all scores for the sentence completion items. For recall, interrater reliability was .95. A third rater was consulted for any disagreement in recall scores to reach a final decision.

In the present study, multivariate analyses of variance (MANOVAs) were used for data analysis. The MANOVAs helped isolate the independent effects of the predictors on the outcomes. Residual correlations were also examined to determine association among measured variables, controlling for differences among the three versions.

Results

Subject Knowledge, L1 Comprehension, and L2 Proficiency

Preliminary analyses examined the relation of subject knowledge, L1 comprehension, and L2 proficiency to the three outcomes, independent of passage version. Residual correlations ensure that version effects are controlled so that pure estimates of the relations of subject knowledge, L1 comprehension, and L2 proficiency to outcomes can be examined. Relevant descriptive statistics for subject knowledge, L1 comprehension, and L2 proficiency appear in Table 2.

Table 2. *Mean Scores and Standard Deviations for Self-Reports of Subject Knowledge (SK), L1 Comprehension, and L2 Spanish Proficiency*

Passage Topic	Mean	SD	Median	Skew	Kurtosis
Eye Passage (SK)	2.20	(0.84)	2	0.81	0.89
Chain Reaction Passage (SK)	3.37	(1.14)	4	-0.56	-0.46
L1 Comprehension	10.59	(3.96)	10.5	0.40	0.21
L2 Spanish Proficiency	72.45	(9.67)	73	-0.47	-0.08

Note. The higher the score the less familiar with text topic; $N = 97$.

For both passages, there was a positive and significant correlation between subject knowledge and comprehension when measured via recall (eye passage, $r = .40, p < .05$; chain reaction passage, $r = .41, p < .05$). Likewise, for both passages there was a significant and positive correlation between subject knowledge and comprehension when measured by multiple choice (eye passage, $r = .23, p < .05$; chain reaction passage, $r = .47, p < .05$). With the eye passage, there was no significant correlation between subject knowledge and comprehension when measured via sentence completion ($r = .19, p > .05$); for the chain reaction passage this relationship was positive and significant ($r = .42, p < .05$).

L1 comprehension was also positively related to the three outcome measures. For the eye passage, greater L1 comprehension was significantly related to recall ($r = .32, p < .05$) and sentence completion ($r = .28, p < .05$) but not to multiple choice ($r = .08, p > .05$). For the chain reaction passage, L1 comprehension was likewise significantly related to recall ($r = .39, p < .05$) and sentence completion ($r = .33, p < .05$) but not to multiple choice ($r = .09, p > .05$).

L2 Spanish proficiency as measured by the online assessment was less consistently related to the passage comprehension measures. For the eye passage, the online assessments (vocabulary, grammar, reading, and total) correlated with the three passage comprehension measures at values that ranged from .07 to .26. Only the correlation between online vocabulary performance and eye passage multiple choice performance ($r = .26, p < .05$) was significant. For the chain reaction passage, the correlations ranged from .06 to .29 and were significant for recall and grammar ($r = .21, p < .05$), recall and vocabulary ($r = .27, p < .05$), recall and total ($r = .26, p < .05$), and

multiple choice and vocabulary ($r = .29, p < .05$).

Textual Enhancement Adjuncts, Subject Knowledge, and Comprehension

MANOVA was used to examine the main effects and interaction of textual enhancement adjuncts and subject knowledge on the three forms of comprehension assessment. Sample means and standard deviations for comprehension as measured via all three comprehension tasks for each passage are listed in Tables 3 and 4. Results of the two MANOVAs (conducted separately for the eye passage and the chain reaction passage) indicated that neither the main effect for version (eye passage, $F(6, 178) = 2.06$, Wilks' $\lambda = .87$, partial $\eta^2 = .065, p > .05$; chain reaction passage, $F(6, 178) = 1.42$, Wilks' $\lambda = .91$, partial $\eta^2 = .046, p > .05$) nor the interaction of textual enhancement adjuncts and subject knowledge (eye passage, $F(6, 178) = 0.75$, Wilks' $\lambda = .95$, partial $\eta^2 = .025, p > .05$; chain reaction passage, $F(6, 178) = 0.95$, Wilks' $\lambda = .94$, partial $\eta^2 = .031, p > .05$) were significant; no follow-up analyses were thus interpreted. Only the main effect of subject knowledge was significant (eye passage, $F(3, 89) = 5.96$, Wilks' $\lambda = .83$, partial $\eta^2 = .167, p < .05$; chain reaction passage, $F(3, 89) = 10.55$, Wilks' $\lambda = .87$, partial $\eta^2 = .262, p < .05$), indicating better comprehension by more knowledgeable participants (as previously reported with the residual correlations). The key finding, however, is that although subject knowledge was positively related to comprehension for both passages, the use of textual enhancements did not compensate for lack of subject knowledge.

Table 3. Descriptive Statistics: Comprehension Assessment Tasks for L2 Eye Passage by Version

Version		Mean	Median	Std. Deviation	Skewness	Kurtosis	n
Recall	No Adjunct	14.39	14	5.14	-0.1	-0.79	33
	Pause Consider Adjunct	14.35	14	6.2	-0.05	-0.66	31
	Adjunct with Written Answer	14.52	15	4.23	0.02	0.24	33
	Total	14.42	14	5.18	-0.06	-0.41	97
Sent Comp	No Adjunct	3.12	3	1.29	-0.05	-1	33
	Pause Consider Adjunct	3.77	4	1.26	-0.83	-0.32	31
	Adjunct with Written Answer	3.91	4	1.23	-1.41	2.25	33
	Total	3.6	4	1.3	-0.67	-0.41	97
Multiple Choice	No Adjunct	3.88	4	0.96	-0.42	-0.73	33
	Pause Consider Adjunct	3.77	4	1.12	-0.75	-0.16	31
	Adjunct with Written Answer	4.18	4	0.98	-1.23	1.68	33
	Total	3.95	4	1.02	-0.79	0.04	97

Table 4. Descriptive Statistics: Comprehension Assessment Tasks for L2 Chain Reaction Passage by Version

	Version	Mean	Median	Std. Deviation	Skewness	Kurtosis	n
Recall	No Adjunct	9.09	9	5.91	0.72	0.23	33
	Pause Consider Adjunct	11.61	10	7.36	0.61	-0.53	31
	Adjunct with Written Answer	9.18	9	6.21	0.48	-0.63	33
	Total	9.93	9	6.54	0.66	-0.2	97
Sent Comp	No Adjunct	3.45	4	1.62	-0.94	-0.16	33
	Pause Consider Adjunct	3.55	4	1.63	-1.03	0.08	31
	Adjunct with Written Answer	3.64	4	1.19	-0.17	-1.51	33
	Total	3.55	4	1.48	-0.87	-0.06	97
Multiple Choice	No Adjunct	3.36	3	1.25	-0.34	-0.75	33
	Pause Consider Adjunct	3.81	4	1.35	-0.75	-0.8	31
	Adjunct with Written Answer	3.91	4	1.23	-0.77	-0.66	33
	Total	3.69	4	1.29	-0.57	-0.88	97

L1 Reading Scores, L2 Textual Enhancements, and L2 Reading Comprehension

Similar analyses were used to examine the main effects and interaction of textual enhancement adjuncts and L1 reading scores (average of standardized recall for the two passages) on the three forms of L2 comprehension assessment. Results of the two MANOVAs indicated that the main effect for version was significant for the eye passage ($F(6, 178) = 2.18$, Wilks' $\lambda = .87$, partial $\eta^2 = .069$, $p < .05$). Follow-up Roy-Bargman step-down tests indicated that the version main effect for sentence completion remained significant once the shared variance of sentence completion with recall and multiple choice was removed ($F(2, 89) = 4.79$, $p < .05$). Bonferroni-corrected pairwise comparisons for sentence completion indicated only that the no-adjunct condition was significantly different from the written answer adjunct condition ($p < .05$). The interaction of textual enhancement adjuncts and L1 reading scores was not significant in either MANOVA (eye passage, $F(6, 178) = 1.10$, Wilks' $\lambda = .93$, partial $\eta^2 = .036$, $p > .05$; chain reaction passage, $F(6, 178) = 0.62$, Wilks' $\lambda = .96$, partial $\eta^2 = .020$, $p > .05$). The main effect of L1 reading scores was significant for each passage (eye passage, $F(3, 89) = 4.39$, Wilks' $\lambda = .87$, partial $\eta^2 = .129$, $p < .05$; chain reaction passage, $F(3, 89) = 8.63$, Wilks' $\lambda = .78$, partial $\eta^2 = .225$, $p < .05$), indicating better L2 comprehension by participants with better L1 comprehension. Although there is some evidence of a version effect in these analyses, the key finding is that although L1 comprehension was positively related to L2 comprehension for both passages, the use of textual enhancements did not compensate for lower L1 comprehension (i.e., no interaction).

L2 Spanish Proficiency, L2 Textual Enhancements, and L2 Reading Comprehension

We also examined the main effects and interaction of textual enhancement adjuncts and L2 Spanish proficiency on the three forms of L2 comprehension assessment. L2 Spanish proficiency was assessed by the online Spanish exam. The total score as well as subscores for grammar, reading, and vocabulary were examined in separate analyses. Results for the resulting eight MANOVAs (separate for each passage, separate for each measure of L2 Spanish proficiency) indicated that the main effects for version were significant for all eye passage outcomes (all $Fs(6, 174) \geq 2.21$, Wilks' $\lambda \leq .85$, partial $\eta^2 \geq .071$, $p < .05$) but not significant for all chain reaction outcomes (all $Fs(6, 178) \leq 1.58$, Wilks' $\lambda > .90$, partial $\eta^2 \leq .052$, $p > .05$). Follow-up Roy-Bargman step-down tests indicated that the version main effect for sentence completion remained significant once the shared variance of sentence completion with recall and multiple choice was removed (all $Fs(2, 89) \geq 4.96$, $p < .05$). Bonferroni-corrected pairwise comparisons for sentence completion indicated only that the no-adjunct condition was significantly different from the written answer adjunct condition ($p < .05$ for all four analyses). All MANOVA interactions were nonsignificant for all outcomes (eye passage, all $Fs(6, 174) \leq 1.31$, Wilks' $\lambda > .92$, partial $\eta^2 \leq .043$, $p > .05$; chain reaction, all $Fs(6, 174) \leq 1.64$, Wilks' $\lambda > .90$, partial $\eta^2 \leq .053$, $p > .05$). The only significant MANOVA effect was the main effect for L2 vocabulary ($F(3, 87) = 3.73$, Wilks' $\lambda = .89$, partial $\eta^2 = .114$, $p < .05$) with the chain reaction passage. This reflects the previously reported significant relations between online vocabulary performance and chain reaction comprehension as assessed by multiple choice and recall. Generally, L2 Spanish proficiency as measured by the online assessment was weakly related to passage comprehension and the textual enhancements did not compensate for lower L2 Spanish proficiency (i.e., all interactions were nonsignificant).

Discussion of Results

This study examined the reading comprehension of adult L2 readers reading two short scientific texts. With both of these texts, prior subject matter knowledge was a significant factor in readers' ability to comprehend what they had read. This factor once again appeared as a contributor to a reader's success in comprehending a text as it did in many studies cited earlier. Most of the research on background knowledge utilized participants from ESL or EFL programs, and the present study lends support for the claim that subject knowledge matters across languages. More specifically, in the present study with learners of Spanish, there was a significant relationship between prior knowledge of both topics and readers' success on the recall and multiple choice measures of comprehension. This finding held true for the sentence completion items with the chain reaction passage, but not with the eye passage. Participants indicated higher degrees of topic familiarity with the eye passage than they did for the chain reaction passage. All participants were adult readers and they need to read to learn new information. Language educators hope to find ways to assist them when they read to learn new information for which prior knowledge may provide only minimal support. The ultimate goal is a successful independent reader, one who can use prior knowledge well but is not overly dependent on it. This study reemphasizes the fact that lower prior knowledge has a debilitating effect on L2 readers' comprehension as seen with the chain reaction passage.

L1 studies suggested that textual enhancement adjuncts in the form of embedded questions might help L2 readers' comprehension and therefore be an avenue toward more independence when

reading. Unfortunately, neither version of the embedded questions facilitated comprehension for readers. This finding was true across the range of prior knowledge scores as well as across the range of L1 recall scores. None of the assessment tasks showed benefits for embedded questions for readers with lower subject matter knowledge (or for lower L1 reading ability) as L1 findings might suggest. In this study, no such evidence was found. Perhaps the relatively low variability among the subject knowledge scores here did not allow for these data to reveal such differences. Most participants indicated that they knew some aspects about the topics, but other aspects were unfamiliar. No participants indicated that they knew a lot about the topics. Therefore, despite prior subject matter knowledge's measured effect on comprehension, any interaction with either format of embedded questions may have gone undetected due to the homogeneous population of subjects. Also, the five-point Likert scale may not have captured a sufficient range of participants' prior knowledge to detect important differences. The self-report instrument may have impacted the results due to test method effect, and this could be a limitation of the present study. A future investigation with L2 readers should examine the type of questions or instruments used to explore topic familiarity. With reading passages from social psychology texts, Brantmeier et al. (2011) reported that the mean score for what-questions was slightly higher than the score for why-questions, and that study's encouraging results led to the present investigation with inserted what-questions. The previous authors suggested that with longer passages more inserted adjuncts may be necessary. The present study uses additional inserted questions with a longer text, but unfortunately, the present study shows that learners may not benefit from what-questions inserted into scientific texts. Future research should continue to examine the benefits of inserted questions with passages with varied topics from different domains with learners at the beginning stages of language learning. Perhaps the use of inserted adjuncts will aid new, less proficient, L2 readers.

The same uncertainty remains about the lack of interaction between embedded questions and L1 reading ability. Interestingly, findings revealed a significant relationship between L1 and L2 recall scores, although this was not a specific research question asked in the present study. The findings of the present study were consistent with Bernhardt's (2005) claim that 50% of one's ability to read in a second language is accounted for by L1 literacy and L2 knowledge. The findings indicated better L2 comprehension with participants who were better at L1 reading, or those who achieved higher L1 reading scores. Unfortunately, the inserted adjuncts did not help the low L1 readers perform better on the L2 reading comprehension tasks. Only in one of the six versions (the eye passage's sentence completion comprehension task) did the task of providing written answers to the adjunct questions improve comprehension for these L2 readers.

The findings support Bernhardt's compensatory model of L2 reading that emphasizes the role of L1 reading abilities on L2 reading results. Nonetheless, the embedded questions did not help weak or strong L1 readers differently despite the variability of L1 scores that provide the opportunity to reveal such a relationship. The implications here are that the embedded questions in L2 texts will not help weaker L1 readers as might have been hoped. In an L1 reading study, Hamaker (1986) reported that embedded questions are particularly beneficial for lower ability L1 readers. One caveat in the present study is that these adult readers may have demonstrated a flagging attention level or diminishing persistence on task when they reached the final English passages. If so, those L1 scores' reflection of actual L1 reading ability may be confounded with the varying motivation to fully complete the tasks.

Finally, we examined the data to determine whether the participants' proficiency in Spanish as measured by the institution's diagnostic exam interacted with the textual enhancements. L2 proficiency in the present study was less consistently related to the L2 comprehension tasks as compared to L1 reading on a similar comprehension task. Interactions were not significant for all outcomes. L2 Spanish proficiency was defined by total score on vocabulary, reading, and grammar, and perhaps future research should further examine this variable and how it is measured. Only one significant factor emerged with this inquiry: L2 vocabulary was positively associated with the chain reaction passage. This echoes earlier findings of the study and underscores the importance of lexical knowledge for L2 reading. Overall, L2 proficiency did not create differing responses to the embedded questions. In other words, neither readers with greater nor lesser L2 proficiency (grammar, vocabulary or reading) gained benefits from the embedded questions. Perhaps these participants, who all placed above the minimal required placement score, once again did not provide a wide enough variance to capture differences that might appear among much weaker or stronger students of Spanish. All of these participants had been tested and placed as having good overall proficiency in their L2. Of course, the alternative explanation is that varying L2 proficiency was not masking differences based on the use of embedded questions. They simply did not improve the performance of any subgroup. Additionally, because all the students placed into the same advanced course, they may not have been totally heterogeneous, even if some of them had very uneven ability profiles. This could have led to a restriction of range, which may have weakened the effect of L2 proficiency.

In summary, textual enhancements in the form of embedded questions did not assist L2 readers to perform better on any of the three comprehension tasks with either of the two passages, other than with sentence completion for the eye passage. With the only significant finding, positive effects were found for the adjunct with a written answer. The effect of textual enhancements on comprehension was not moderated by L1 reading, L2 overall proficiency or prior subject matter knowledge. This study provided strong evidence that embedded questions do not aid L2 reading comprehension. The study demonstrated once again that techniques used to teach L1 reading do not always work in the L2 setting. It further revealed that significantly improving reading comprehension is not an easy outcome to obtain from experimental L2 studies. In many settings "reading is often inseparable from learning, necessitating both understanding and retaining complex, often unfamiliar concepts" (Koda, 2004, p. 204). Language educators need more innovations to help learners become accomplished L2 readers. Important clues may yet be hidden by other learner differences.

Areas for Future Research

The success of various aids to L2 comprehension may vary along a number of different individual characteristics and therefore may not yet be revealed until individual learners are encouraged to explore what helps them, as individuals, most. For example, further research may find differing effects for adjuncts based on gender, individual learning style preferences, or ability to monitor understanding. Future studies of this type could also examine whether different major areas of study affect the homogeneity of data. The present study utilized learners from the advanced levels of instruction, and perhaps in future experiments different findings may emerge

with true beginners or learners at the intermediate levels of instruction as the inserted adjuncts may benefit readers at the lower levels. Types of adjuncts, rather than embedded questions, may also prove to be more powerful aids to L2 readers. For example, the type of questions may determine whether the L2 reader comprehends unknown vocabulary or whether the reader is able to generate a mental representation of the topic. Greenleaf et al. (2011), working in the area of L1 reading comprehension, suggested that instruction in how to flexibly choose from an “array of comprehension tools” may assist readers of science texts more than learning “a particular comprehension strategy or set of strategies” (p. 657). This advice based on L1 studies may yet be the element that proves true in L2 as well and merits further investigation.

Future research could also use larger sample sizes with the multivariate multiple regression analysis so that all of the dependent variables can be combined into a single model, rather than separating them into different ones. The sample size of the present study was 97, so this was unavoidable, but future investigations may do well to improve on this. Lastly, the current study was not an attempt to examine how well the researchers can predict scores on comprehension from the scores on two or more independent variables because preliminary work on the topic needed to be completed before examining what combination of variables best predicts scores on comprehension tests. Eventually, regression analysis (or related statistical procedures) might be a worthwhile tool for considering the predictive value of some of the variables in question. In this way, other categorical data might also be incorporated more easily, such as gender or attitudinal categories. For such an analysis to be productive (or in other words to increase the chances of detecting significant relationships) a larger number of participants may be necessary. In light of new issues raised about L2 reading research methodologies (Bernhardt, 2011), a future inquiry of this type should be concerned with the amounts and types of variables that are superior, or more influential, in producing higher levels of reading comprehension (Brantmeier, 2004).

Notes

1. Syntactic complexity was defined by the number of embedded clauses per sentence.
2. Hammadou (2000) included both the correct idea units recalled from the scientific passage as well as the analogic additions, and then calculated the percentage that was correct based on the text versions.

References

Alexander, P. A., & Kulikowich, J. M. (1991). Domain knowledge and analogic reasoning ability as predictors of expository text comprehension. *Journal of Reading Behavior*, 23, 165–190. doi: 10.1080/10862969109547735

Anderson, R. C., & Pearson, P. D. (1984). A schema-theoretic view of basic processes in reading comprehension. In P. D. Pearson (Ed.), *Handbook of reading research* (pp. 255–291). New York: Longman.

Ausubel, D. (1960). The use of advance organizers in the learning and retention of meaningful verbal material. *Journal of Educational Psychology*, 51, 267–272.

Bamford, J., & Day, R. R. (1998). Teaching reading. *Annual Review of Applied Linguistics*, 18, 124–141. doi: 10.1017/S0267190500003512

Barry, S., & Lazarte, A. (1995). Embedded clause effects on recall: Does high prior knowledge of content domain overcome syntactic complexity in students of Spanish? *The Modern Language Journal*, 79, 491–504. doi: 10.1111/j.1540-4781.1995.tb05449.x

Bean, T. W., Searles, D., & Cowen, S. (1990). Text-based analogies. *Reading Psychology: An International Quarterly*, 11, 323–333. doi: 10.1080/0270271900110403

Bernhardt, E. B. (1991). *Reading development in a second language*. Norwood, NJ: Ablex.

Bernhardt, E. B. (2005). Progress and procrastination in second-language reading. In Mary McGroarty (Ed.). *Annual Review of Applied Linguistics*, 25 (pp. 133–150). Cambridge: CUP.

Bernhardt, E. B. (2011). *Understanding advanced second-language reading*. New York: Routledge.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior*, 11, 717–726. doi: 10.1016/S0022-5371(72)80006-9

Brantmeier, C. (2002). The effects of passage content on second language reading comprehension by gender across instruction levels. In J. Hammadou Sullivan (Ed.), *Research in second language learning: Literacy and the second language learner* (pp. 149–176). Greenwich, CT: Information Age Publishing.

Brantmeier, C. (2003). Does gender make a difference? Passage content and comprehension in second language reading. *Reading in a Foreign Language*, 15, 1–27.

Brantmeier, C. (2004). Statistical procedures for research on L2 reading comprehension: An examination of regression models and ANOVA. *Reading in a Foreign Language*, 16, 51–69.

Brantmeier, C. (2005). Effects of reader's knowledge, text type, and test type on L1 and L2 reading comprehension. *The Modern Language Journal*, 89, 37–53. doi: 10.1111/j.0026-7902.2005.00264.x

Brantmeier, C., Callender, A., & McDaniel, M. (2011). The effects of embedded and elaborative interrogation questions on reading comprehension with advanced second language learners. *Reading in a Foreign Language*, 23, 238–247.

Bügel, K., & Buunk, B. P. (1996). Sex differences in foreign language text comprehension: The role of interests and prior knowledge. *The Modern Language Journal*, 80, 15–31. doi: 10.1111/j.1540-4781.1996.tb01133.x

Callender, A. A., & McDaniel, M. A. (2007). The benefits of embedded questions for low and high structure builders. *Journal of Educational Psychology*, 99, 339–348. doi: 10.1037/0022-0663.99.2.339

Carrell, P. L. (1984a). The effects of rhetorical organization on ESL readers. *TESOL Quarterly*, 18, 441–469. doi: 10.2307/3586714

Carrell, P. L. (1984b). Evidence of a formal schemata in second language comprehension. *Language Learning*, 34, 87–112. doi: 10.1111/j.1467-1770.1984.tb01005.x

Carrell, P. L. (1991). Second language reading: Reading ability or language proficiency. *Applied Linguistics*, 12, 159–179. doi: 10.1093/applin/12.2.159

Clarke, M. A. (1980). The short circuit hypothesis of ESL reading – or when language competence interferes with reading performance. *The Modern Language Journal*, 64, 203–209. doi: 10.1111/j.1540-4781.1980.tb05186.x

Glynn, S., Britton, B., & Muth, K. (1985). Text-comprehension strategies based on outlines: Immediate and long-term effects. *Journal of Experimental Education*, 53, 129–135. doi: 10.1080/00220973.1985.10806373

Greenleaf, C. L., Litman, C., Hanson, T. L., Rosen, R., Boscardin, C. K., Herman, J., & Schneider, S. A. (2011). Integrating literacy and science in Biology teaching and learning impacts of reading apprenticeship professional development. *American Educational Research Journal*, 48, 647–717. doi: 10.3102/0002831210384839

Guo, Y., & Roehrig, A. D. (2011). Roles of general versus second language (L2) knowledge in L2 reading comprehension. *Reading in a Foreign Language*, 23, 42–64.

Hamaker, C. (1986). The effects of adjunct questions on prose learning. *Review of Educational Research*, 56, 212–242. doi: 10.3102/00346543056002212

Hammadou, J. (1990). The effects of analogy on French reading comprehension. *The French Review*, 64, 239–252.

Hammadou, J. (2000). The impact of analogy and content knowledge on reading comprehension: What helps, what hurts. *The Modern Language Journal*, 84, 38–50. doi: 10.1111/0026-7902.00051

Hammadou Sullivan, J. A. (2002). Advanced foreign language readers' inferencing. In J. A. Hammadou Sullivan (Ed.). *Literacy and the second language learner* (pp. 217–238). Greenwich, CT: Information Age Publishing.

Hudson, T. (1982). The effects of induced schemata on the short-circuit in L2 reading: Non-decoding factors in L2 reading performance. *Language Learning*, 32, 1–32. doi: 10.1111/j.1467-1770.1982.tb00516.x

Johnson, P. (1981). Effects on reading comprehension of language complexity and cultural background of a text. *TESOL Quarterly*, 15, 169–181. doi: 10.2307/3586408

Johnson, P. (1982). Effects on comprehension of building background knowledge. *TESOL Quarterly*, 16, 503–516. doi: 10.2307/3586468

Koda, K. (2004). *Insights into second language reading: A cross-linguistic approach*. Cambridge, UK: Cambridge University Press.

Lee, J. F. (1986). On the use of the recall task to measure L2 reading comprehension. *Studies in Second Language Acquisition*, 8, 201–212. doi: 10.1017/S0272263100006082

Lee, J. F. (1990). A review of empirical comparisons of nonnative reading behaviors across stages of language development. In H. Burmeister & P. Rounds (Eds.), *Variability in second language acquisition* (pp. 453–472). Eugene, OR: University of Oregon Press.

Lorch, R. F., & Lorch, E. P. (1985). Topic structure representation and text recall. *Journal of Educational Psychology*, 77, 137–148. doi: 10.1037/0022-0663.77.2.137

Meyer, B. J. F. (1985). Prose analysis: Purposes, procedures, and problems. In B. K. Britton & J. B. Black (Eds.), *A theoretical and practical handbook for analyzing explanatory text* (pp. 11–52). Hillsdale, NJ: Lawrence Erlbaum.

MLA Ad Hoc Committee on Foreign Languages (2009). Foreign languages and higher education: New structures for a changed world. Retrieved from: <http://mla.org/flreport>

Mohammed, M. A., & Swales, J. M. (1984). Factors affecting the successful reading of technical instructions. *Reading in a Foreign Language*, 2, 206–217.

Ozgungor, S., & Guthrie, J. T. (2004). Interactions among elaborative interrogation, knowledge, and interest in the process of constructing knowledge from text. *Journal of Educational Psychology*, 96, 437–443. doi: 10.1037/0022-0663.96.3.437

Peverly, S., & Wood, R. (2001). The effects of adjunct questions and feedback on improving the

reading comprehension skills of learning-disabled adolescents. *Contemporary Educational Psychology*, 26, 25–43. doi: 10.1006/ceps.1999.1025

Pritchard, R. (1990). The effects of cultural schemata on reading processing strategies. *Reading Research Quarterly*, 25, 273–295.

Schueller, J. (1999). *The effect of two types of strategy training on foreign language reading comprehension: An analysis by gender and proficiency* (Unpublished doctoral dissertation). The University of Wisconsin, Madison.

Seifert, T. L. (1993). Effects of elaborative interrogation with prose passages. *Journal of Educational Psychology*, 85, 642–651. doi: 10.1037/0022-0663.85.4.642

Shohamy, E. (1982). Affective considerations in language testing. *The Modern Language Journal*, 66, 13–17. doi: 10.1111/j.1540-4781.1982.tb01015.x

Shohamy, E. (1984). Does the testing method make the difference? The case of reading comprehension. *Language Testing*, 1, 147–170. doi: 10.1177/026553228400100203

Stahl, S., Hare, V. C., Sinatra, R., & Gregory, J. (1991). Defining the role of prior knowledge and vocabulary in reading comprehension: The retiring of number 41. *Journal of Reading Behavior*, 23, 487–508.

Steffensen, M. S., Joag-Dev, C., & Anderson, R. C. (1979). A cross-cultural perspective on reading comprehension. *Reading Research Quarterly*, 15, 10–29.

Van den Broek, P. (1994). Comprehension and memory of narrative texts: Inferences and coherence. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 539–588). San Diego: Academic Press.

Vosniadou, S., & Brewer, W. F. (1987). Theories of knowledge restructuring in development. *Review of Educational Research*, 57, 51–67. doi: 10.3102/00346543057001051

Vosniadou, S., & Ortony, A. (1983). The influence of analogy in children's acquisition of new information from text: An explanatory study. In J. A. Niles & L. A. Harris (Eds.), *Searches for meaning in reading/language processing and instruction* (pp. 71–79). Rochester, NY: National Reading Conference.

Walczuk, J., & Hall, V. (1989). Effects of examples and embedded questions on the accuracy of comprehension self-assessments. *Journal of Educational Psychology*, 81, 435–437. doi: 10.1037/0022-0663.81.3.435

Wise, J. C., Sevcil, R. A., Morris, R. D., Lovett, M. W., & Wolf, M. (2007). The relationship among receptive and expressive vocabulary, listening comprehension, pre-reading skills, word identification skills, and reading comprehension by children with reading disabilities. *Journal of Speech, Language, and Hearing Research*, 50, 1093–1109. doi: 10.1044/1092-4388(2007/076)

Wolf, D. (1993). A comparison of assessment tasks used to measure FL reading comprehension. *The Modern Language Journal*, 77, 473–489. doi: 10.1111/j.1540-4781.1993.tb01995.x

Young, D. J., & Oxford, R. (1997). A gender-related analysis of strategies used to process input in the native language and a foreign language. *Applied Language Learning*, 8, 43–73.

Appendix A

Selections from Passages

Eye passage (translation)

THE EYE

The eye is the organ of sight. Thanks to it, we can determine the distance, color and volume of beings and things around us.

The role of the eye is to perceive illuminated objects. It focuses on them and projects an image on the retina. The retina in turn analyzes this image and transmits the visual message to the brain. This entire mechanism is necessary in order for us to see.

Pause to consider... (or please write down your answer to the following question)
What is the function of the retina?

CHAIN REACTIONS (translation)

Chain reactions are chemical or physico-chemical reactions whose speed increases rapidly and which become explosive. The nuclear fission reaction, for example of uranium, is a chain reaction.

Pause to consider... (or please write down your answer to the following question)
What is a chain reaction?

When a uranium atom receives a neutron, it disintegrates into several lighter atoms and emits energy and several new neutrons. Each neutron will be able to strike another uranium atom, which in turn will disintegrate emitting several neutrons.

The speed of the nuclear reaction, which is the number of disintegrations by unit of time, increases exponentially and becomes infinitely large—this is the explosion.

For there actually to be an explosion, it is necessary for the emitted neutrons to be able to strike the uranium atoms. For that to happen, a sufficiently large number of uranium atoms is needed. In other words, a large enough mass is needed. If the sample of uranium has a mass less than a certain value, called critical mass, too many neutrons escape from the sample without having encountered any other uranium atoms. Then the speed of the reaction remains low.

Pause to consider... (or please write down your answer to the following question)
What conditions are necessary to cause an explosion?

About the Authors

Cindy Brantmeier is Chair of the Department of Education and Professor of Applied Linguistics and Education at Washington University in St. Louis. She is principal investigator in the Language Research Lab, director of the Program in Applied Linguistics, and co-director of the Graduate Certificate in Language Instruction. Dr. Brantmeier has published articles concerning interacting variables in adult second language reading, language research methodology, testing and assessment, and other related areas in journals such as *The Modern Language Journal, System, Foreign Language Annals*, and *Reading in a Foreign Language*, among others. She is also editor of several volumes and a book on adult foreign language reading. E-mail: cbrantme@wustl.edu

JoAnn Hammadou Sullivan is a professor of French and Foreign Language Education at the University of Rhode Island where she is a program leader for world language education. She has served on the Board of Examiners for the National Council for Accreditation of Teacher Education (NCATE) and the Annual Report Committee for the Council for the Accreditation of Educator Preparation (CAEP). She is the founding editor and series editor of *Research in Second Language Learning*. Dr. Hammadou Sullivan has published research articles on a range of topics from reading comprehension to teacher evaluations in journals such as *Modern Language Journal, Foreign Language Annals, French Review* and *Reading in a Foreign Language*. She is

also author of a textbook on French composition, *Liens par écrit*. E-mail: joannh@uri.edu

Michael Strube is Professor of Psychology and Director of the Social Behavior Laboratory in the Department of Psychology at Washington University in St. Louis. Dr. Strube has published articles on the motives underlying the acquisition of self-knowledge, the evolutionary basis for narcissism, environmental attitudes, and the application of research design and statistics. He is a former editor of *Basic and Applied Social Psychology*. E-mail: mjstrube@wustl.edu